Course no. BIOE 420 **Course title: Transport Phenomena in BIOE**

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Course description: BIOE 420 will cover transport phenomena as applied to biological systems. Through lectures, in-class quizzes, assignments, and exams, conservation of momentum and mass equations will be derived and used to characterize transport of fluids and mass in biology, physiology, and in biomedical devices. This course synthesizes much of the content learned in BIOE 252 and 322 and applies knowledge from BIOE 372 and 391.BIOE 420 is designed for senior bioengineering students.

Course prerequisites: MATH 211 AND MATH 212 AND (BIOE 332 OR CHBE 411) AND BIOE 391
What are the concepts and critical skills these prerequisites imply that students must know to take this course? Ordinary differential equations; linear algebra; multivariable calculus; conservation of mass and momentum; numerical methods; basic biology/physiology knowledge

Course credit: 3 hrs
Class schedule: MW 11-12:15pm, Location BRC 284
Course URL: Rice Canvas

Textbooks:

Required: *Transport Phenomena in Biological Systems, 2nd Ed., Truskey, Yuan, and Katz*
Supplemental (not required): *Transport Phenomena, Revised 2nd Ed., Bird, Stewart, and Lightfoot*

Course objectives:
Students should learn

1. To apply governing equations for momentum transport (Newton's law of viscosity, Navier-Stokes equations) [Course outcomes 1, 3]
2. To apply governing equations for mass transport (Fick's law, diffusion and convection/diffusion equation) [Course outcomes 2, 3]
3. To apply governing equations for transport through membranes [Course outcome 4]

Course outcomes:
Student completing the course should be able to

1. Calculate time-independent and time-dependent laminar fluid flow properties in simple geometries in 1, 2, and 3 dimensions
2. Calculate time-independent and time-dependent mass diffusion in simple geometries in 1, 2, and 3 dimensions
3. Carry out dimensional analysis in context of fluid and mass transport
4. Calculate diffusion coefficients
5. Recognize current technological challenges related to momentum/mass transfer in bioengineering

Relationship of course outcomes to student outcomes:

Course Outcome	Student Outcome	Assessment Methods
1	1 (PI 1d), 5 (PI 5b), 8 (PI 8b)	HW 1-4, Exams 1 and 2
2	1 (PI 1d), 5 (PI 5b), 8 (PI 8b)	HW 5-7, Exams 3 and 4
3	1 (PI 1d), 5 (PI 5b), 8 (PI 8b)	HW 4 and 7, Exams 2 and 4
4	1 (PI 1d), 5 (PI 5b), 8 (PI 8b)	HW 5, Exam 3

Topics covered:
Examples of momentum and mass transfer in biological systems
Conservation relations for momentum and mass
Constitutive equations for momentum and mass transport
Dimensional analysis and dimensionless groups
Diffusion with electrical potentials or convection

Scheduling: BIOE 420 is offered in the fall semester
Professional Component Content: Engineering (3 hrs)

Grading:
Final course grades will be based on

Participation and Quizzes	**15%**
Problem Sets	**35%**
Exams, in-class	**50%**

Grading scale:

A+	97-100	C+	77-79
A	93-96	C	73-76
A-	90-92	C-	70-72
B+	87-89	D+	67-69
B	83-86	D	63-66
B-	80-82	D-	60-62
		F	< 60

Exams:
There will be 4 closed book, closed notes exams. The exams will be in-class. Equations reference sheets will be distributed prior to the exam date and will be provided at the exam.

Exam re-grade policy: Please submit requests for re-grades in writing to the co-instructor or TAs within 2 days of receiving your graded exam. The entire problem will be regraded. Be warned that a failed appeal will result in an exam grade penalty of -5%.

Quizzes:
There are 19 quizzes scheduled but only 17 will be counted, which means students can miss 2 quizzes. In the event of illness/family emergencies/school interviews, please notify the instructor as soon as possible to schedule a make-up quiz outside of the lecture period. Quizzes will not be re-graded.

Problem sets:
Problem sets will be posted through Canvas approximately one week before the due date. Hard copies of problem sets are due at the beginning of class on due dates. Late problem sets will be docked 10% every 30 minutes past the due time. Please ensure problem sets are very easy to read and all steps involved in solving the problems are shown.

Problem set re-grade policy: Please submit requests for re-grades in writing to your TA within 2 days of receiving your graded problem set. Be warned that a failed appeal will result in a problem set grade penalty of -5%.

Attendance policy:
Students are expected to attend all lectures. Instructor must be notified of illness/family emergencies/school interviews as soon as possible and will be handled on an individual basis. *Lecture attendance and class participation will be strongly considered when determining final grades.*

Honor code policy:
Students are encouraged to talk to each other, the TA, the instructor, or anyone else about material in the course that is not specifically designated as pledged. This assistance is limited to the discussion of the problem and sketching of a solution. Students must complete their own work. Students are prohibited from looking at solution keys obtained through whatever means, including the internet, students who have taken the course before, students at other universities, etc. Students must log off and remain logged off of Owlspace during the in-class exams. During the exam, use of cell phones, laptops, and other digital devices at any point, even for non-course related activities and even physically outside of the classroom, is strictly prohibited.

Electronics policy:
Cell phone usage, social media, etc. are prohibited during lectures. Violations of this policy will **severely and negatively impact student participation grades.**

Disabilities:
Any student with a documented disability seeking academic adjustments or accommodations is requested to speak with the instructor during the first two weeks of class. All such discussions will remain as confidential as possible. Students with disabilities will need to also contact Disability Resource Center.

Approximate schedule of topics* **(*may be updated as semester progresses)**

BIOE 420 Transport Phenomena in BIOE

	Lecture	Date	Topic	Truskey Chapter	Truskey Pages	Quiz	Problem Sets
MODULE 1	1	Mon; 8/20/2018	Intro to biotransport; Conservation of mass & momentum	Ch. 1, 2	1-11, 55-67		
		Wed; 8/22/2018	*NO CLASSES - CSHL Genome Engineering*				
	2	Mon; 8/27/2018	Couette flow; Newton's Law of Viscosity; Shear stress; Viscosity; Non-Newtonian fluids	Ch. 2	74-79, 82-88	Q1	
	3	Wed; 8/29/2018	Couette flow continued; General problem solving strategy			Q2	PS1 reminder
		Mon; 9/3/2018	*NO CLASSES - Labor Day*				
	4	Wed; 9/5/2018	P-driven flow through narrow rectangular channel	Ch. 2	88-92	Q3	
	5	Mon; 9/10/2018	P-driven flow through cylindrical tube	Ch. 2	92-97	Q4	PS1 DUE, PS2 reminder
MODULE 2		Wed; 9/12/2018	*NO CLASSES - Science Park*				
	6	Mon; 9/17/2018	Math review - Discussion Session with TAs prep for Ch.3; General form of Conservation of Mass	Ch. 3	120-125	Q5	
	7	Wed; 9/19/2018	General form of Conservation of Momentum	Ch. 3	125-131	Q6	PS2 DUE
		Mon; 9/24/2018	**EXAM 1**				
	8	Wed; 9/26/2018	Navier-Stokes equations	Ch. 3	131-136	Q7	PS3 reminder
	9	Mon; 10/1/2018	Fluid motion with more than one dependent variable	Ch. 3	136-145	Q8	
	10	Wed; 10/3/2018	Fluid motion with more than one dependent variable (cont.)			Q9	PS3 DUE, PS4 reminder
		Mon; 10/8/2018	*NO CLASSES - Midterm recess*				
	11	Wed; 10/10/2018	Fluid motion with more than one dependent variable (cont.)			Q10	
MODULE 3	12	Mon; 10/15/2018	Fick's laws of diffusion; Diffusion coefficient	Ch. 6	261-269, 277-280, 288-289	Q11	
		Wed; 10/17/2018	*NO CLASSES - BMES*				PS4 DUE
		Mon; 10/22/2018	**EXAM 2**				
	13	Wed; 10/24/2018	1D steady-state diffusion across membrane & through 2-phase medium	Ch. 6	288-299	Q12	PS5 reminder
	14	Mon; 10/29/2018	1D unsteady diffusion through semi-infinite medium	Ch. 6	300-310	Q13	
	15	Wed; 10/31/2018	1D unsteady diffusion through semi-infinite medium (cont.)	Ch. 6		Q14	PS5 DUE, PS6 reminder
	16	Mon; 11/5/2018	1D unsteady diffusion in finite medium	Ch. 6	310-316	Q15	
		Wed; 11/7/2018	*NO CLASSES - TMC Symposium*				
	17	Mon; 11/12/2018	1D unsteady diffusion in finite medium, spherical coordinates			Q16	
MODULE 4	18	Wed; 11/14/2018	General form of mass transport equations	Ch. 7	346-355	Q17	PS6 DUE, PS7 reminder
		Mon; 11/19/2018	**EXAM 3**				
		Wed; 11/21/2018	*NO CLASSES - Thanksgiving Travel*				
	19	Mon; 11/26/2018	Diffusion and convection	Ch. 7	370-378	Q18	
	20	Wed; 11/28/2018	Diffusion and convection (cont.)			Q19	PS7 Due
		Finals wk	**EXAM 4**				